BULLETIN 420 MAY, 1928

Fertilizers for Early Cabbage, Tomatoes, Cucumbers, and Sweet Corn

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OHIO
AGRICULTURAL EXPERIMENT STATION
Wooster, Ohio

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FERTILIZERS FOR EARLY CABBAGE, TOMATOES, CUCUMBERS, AND SWEET CORN

DONALD COMIN AND JOHN BUSHNELL

SUMMARY OF PRACTICAL CONCLUSIONS

A fertilizer experiment on four early truck crops, cabbage, tomatoes, cucumbers, and sweet corn, has been in progress for twelve years at the Washington County Experiment Farm, near Marietta in southeastern Ohio.

The soil of the experimental area varies from loam to fine sandy loam and is typical of much of the soil of the Muskingum River terrace. The four crops are grown in rotation on plots receiving annually various fertilizer, manure, and lime treatments. Fall cover crops are grown after each marketed crop.

On this acid soil (pH about 5.6) ground limestone, applied at the rate of one ton annually, was beneficial to cabbage; but in conjunction with manure or a complete chemical fertilizer, it had no significant effect on the tomatoes, cucumbers, or sweet corn.

The results from the three principal fertilizer constituents applied in various combinations on limed plots (pH about 7.0) were as follows:

(1) Nitrate of soda with superphosphate (acid phosphate) gave larger yields of tomatoes, cucumbers, and cabbage than either of these fertilizers alone, showing that both nitrogen and phosphoric acid were essential to these crops. On sweet corn nitrogen fertilizers were beneficial; superphosphate was not.

(2) Potash added to a mixture of the other two constituents further increased the yield of tomatoes, but had no significant effect on the yield of the other crops.

Manure, at a cost of $3.75 per ton, and applied at the rate of 16 tons per acre, was more profitable than chemical fertilizers on cucumbers. The yields of tomatoes and sweet corn were higher with manure, but the difference was not sufficient to cover the higher cost of the manure. Chemical fertilizers gave the largest yields when applied for cabbage.

Superphosphate and manure gave better results with tomatoes than manure alone.

Nitrate of soda, supplementing manure and superphosphate, increased the yield of both cabbage and cucumbers.

Fertilizer recommendations for each of the crops are based on the following deductions:

For **cabbage** lime was essential. Nitrogen and phosphoric acid fertilizers were also essential where no manure was applied. As to the amount of nitrogen required, it was found that a mixed fertilizer containing 480 pounds of nitrate of soda per acre (about 75 pounds of nitrogen) gave higher yields than a smaller application. Dividing the nitrate of soda into two parts and applying half of it after the plants were established in the field gave better results than applying the entire amount when fitting the soil. There was no comparison in the experiment from which the amount of phosphoric acid needed in a chemical fertilizer might be deduced. The fact that there was no significant effect from the addition of superphosphate to 16 tons of manure per acre indicates that the cabbage crop did not require more phosphoric acid than was supplied by the manure (about 64 pounds, equivalent to 400 pounds of 16 percent superphosphate). Manure alone did not give as high yields of cabbage as some of the chemical fertilizer combinations. Nitrate of soda added to manure gave excellent results.

For **tomatoes** a complete fertilizer was required. A mixture composed of 320 pounds per acre of nitrate of soda, 800 pounds of 16 percent superphosphate, and 100 pounds of muriate of potash gave higher yields than any other combination tested. Sixteen tons of manure per acre, supplemented with superphosphate gave slightly larger yields than this complete chemical fertilizer, but the difference was not sufficient to compensate for the higher cost of the manure.

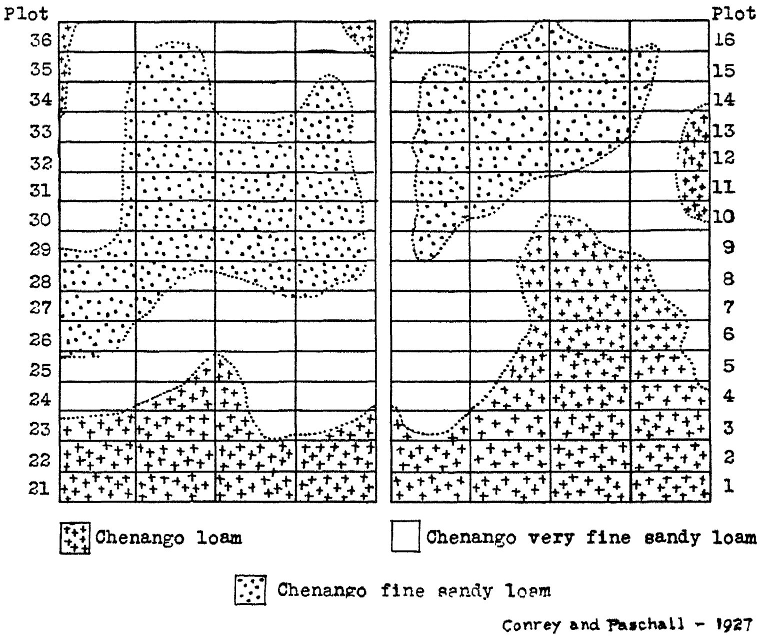
For **cucumbers** nitrogen and phosphoric acid fertilizers were essential. Nitrate of soda at the rate of 480 pounds per acre, supplemented with superphosphate, gave conspicuous increases. This was the largest amount of nitrate of soda tried, but the fact that manure was beneficially supplemented by nitrate of soda indicated that more nitrate might prove profitable. At the rate of 16 tons per acre, manure gave much larger yields and was more profitable on cucumbers than any of the chemical fertilizer mixtures. The addition of superphosphate to manure was of no benefit. Evidently the cucumber crop did not need more phosphoric acid than was supplied by the manure (about 64 pounds per acre).

For **sweet corn** nitrogen was the only chemical fertilizer constituent that gave significant increases in yield. Manure produced slightly larger yields than nitrogen fertilizers, but at prevailing prices, the increase from the manure treatment was not profitable.

INTRODUCTION

Vegetable growers, because of the decreasing supply of animal manure, are forced to rely more and more upon commercial fertilizers and cover crops for the maintenance of soil fertility. In many places, manure being prohibitive in price, chemical fertilizers are used in large amounts. This change in practice has come about so rapidly that many questions involving the economical use of chemical fertilizers, the best use to make of the manure that may be available, and the permanent maintenance of soil fertility without animal manure, remain unanswered.

To answer such questions, an experimental truck farm of 10 acres on a terrace of the Muskingum River in the Marietta district of southeastern Ohio was acquired in 1914. The soil is typical of much of the terrace soil of the district. The accompanying map gives the results of a recent soil survey by G. W. Conrey and A. H. Paschall of the area set aside for fertilizer plots. The farm was in a relatively low state of fertility when acquired for experimental purposes. A general description of the farm and the district is given in Ohio Experiment Station Bulletin 377.



Soil map of the experimental area

The farm is operated as part of the Washington County Experiment Farm, under the general supervision of the Experiment Station staff. Details of operation are under the supervision of O. N. Riley, who has been foreman since the farm was acquired, and to whom much credit is due for the success of the experiments reported here.

PLANS AND METHODS

The fertilizer experiment was laid out as shown on the map and started in 1915. The four leading crops of the district—tomatoes, cabbage, cucumbers, and sweet corn—have been planted each year in a regular four-year rotation. That is, the four crops are planted across the treatments, so that each plot is actually divided into four small plots. Records are therefore taken each year on 128 one-fortieth acre plots.

The fertilizer and manure, in amounts as shown on page 7, are broadcast at the time of fitting the ground early in the spring, except as noted on Plot 14. All plots of series A receive ground limestone at the rate of 2 tons per acre biennially. In this series the untreated plots as well as the fertilized plots are limed. In series B, only the plots designated as limed receive lime, annual applications being made at the rate of 1 ton of ground limestone per acre.

To aid in maintaining the organic content of the soil, soybeans are sown thruout series A and on part of series B after the cabbage is harvested, and among the tomatoes and sweet corn at the last cultivation. The soybeans are disked before frost and rye is sown over the entire experimental area. On Plots 21 to 28 in series B, which constitute a manure experiment, the soybean cover crop is omitted.

The varieties and cultural practices follow closely those of the district. The crops are grown for early shipment, hence the following varieties were adopted:

Copenhagen Market cabbage, small-head type
Bonny Best tomatoes
White Spine type of cucumber
Livingston's Early Sugar sweet corn

In spacing the plants, some consideration was given to the shape of the plots. The actual planting distances in the last four years were as follows:

Cabbage 36 by 14 inches
Tomatoes 50 by 24 inches, staked and pruned to 1 stem
Cucumbers 50 by 34 inches, 3 plants per hill
Sweet corn 36 by 34 inches, 3 plants per hill

PLAN OF FERTILIZER EXPERIMENT AT WASHINGTON COUNTY TRUCK FARM

Annual treatments* in pounds per acre for the four-year period, 1923-1926, inclusive. Plots 1/10 acre

SERIES A†

Plot	Treatment
1	Unfertilized
2	Manure, 16 tons Superphosphate, 800 lb.
3	Manure, 16 tons
4	Unfertilized
5	Manure, 20 tons
6	Superphosphate, 800 lb. Nitrate of soda, 320 lb. Muriate of potash, 100 lb.
7	Unfertilized
8	Superphosphate, 1200 lb. Nitrate of soda, 480 lb. Muriate of potash, 150 lb.
9	Superphosphate, 800 lb. Nitrate of soda, 320 lb.
10	Unfertilized
11	Superphosphate, 800 lb.
12	Sulfate of ammonia, on cucumbers and cabbage, 390 lb. On tomatoes and sweet corn, 260 lb.
13	Unfertilized
14	Same as Plot 15 in two applications
15	Nitrate of soda in one application On cucumbers and cabbage, 480 lb. On tomatoes and sweet corn, 320 lb.
16	Unfertilized

SERIES B

Plot	Treatment
21	Manure, 8 tons; ground limestone, 1 ton Superphosphate, 800 lb. Nitrate of soda, 320 lb. Muriate of potash, 100 lb.
22	Unfertilized
23	Manure, 16 tons Superphosphate, 400 lb. Nitrate soda, 160 lb.; mur. potash, 50 lb.
24	Manure, 16 tons
25	Manure, 16 tons Ground limestone, 1 ton
26	Manure, 16 tons; ground limestone, 1 ton Superphosphate, 400 lb. Nitrate of soda, 160 lb.
27	Manure, 16 tons
28	Manure, 16 tons Superphosphate, 400 lb. Ground limestone, 1 ton
29	Unfertilized
30	Superphosphate, 400 lb. Nitrate of soda, 160 lb. Muriate of potash, 50 lb.
31	Superphosphate, 400 lb. Nit. soda. 160 lb.; mur. potash, 50 lb. Ground limestone, 1 ton
32	Unfertilized
33	Ground limestone, 1 ton
34	Superphosphate, 400 lb. Nitrate of soda, 160 lb. Ground limestone, 1 ton
35	Unfertilized
36	Superphosphate, 400 lb. Ground limestone, 1 ton

*During the first eight years of the experiment, 1915-1922, inclusive, some of the plots received the same treatments as shown here; on others the applications were smaller. The earlier treatments are given with the tables of yields.

†Ground limestone is applied to all the plots of series A every second year at the rate of 2 tons per acre.

The cabbage and tomatoes are started under glass and transplanted to the field; the cucumbers and sweet corn are planted directly in the field.

Changes in plan.—At the close of the first eight years of the experiment, when two cycles of the four-year rotation had been completed, it was evident that some of the fertilizer treatments could profitably be increased, hence a number of changes were made. The revised treatments only are shown on page 7 the earlier applications are presented with the tabulated results of the first eight years. In the present report, special emphasis is placed on the results of the last four years.

CALCULATION OF YIELDS AND RECEIPTS

Every third plot in most of the experimental area is left unfertilized to serve as a check in calculating the increases due to the fertilizer treatments and to correct for variations in the soil of the experimental area as a whole. The increases in yield are calculated according to the method used by Thorne.[1] As he explained, "It is assumed that variations in the soil are progressive and that if the yields on Plots 1 and 4 were 6 and 9 bushels, respectively, Plots 2 and 3 should have yielded 7 and 8 bushels, respectively, if left unfertilized." In comparing treatments, then, more confidence is placed in the calculated increases over the untreated checks than in the actual yields.

In the manure experiment, Plots 21 to 28, there is only one unfertilized plot, and this is not strictly comparable to the other unfertilized plots for it has no soybean cover crop. The average yield of Plots 22 and 29 was arbitrarily used in calculating the increases due to the manure treatments.

The experimental area is nearly level and excellently adapted for fertility studies. Nevertheless, several instances are found where there is doubt as to whether a small average difference in yields is due to the fertilizer treatments or to the unavoidable fluctuations that occur in all field experiments. Where a small difference is of special interest the data have been critically examined to determine the constancy of the difference from year to year, and the results of this examination are expressed, following Love's modification of Student's method,[2] as the "odds" that the difference is actually due to the treatment. Where the odds are

[1]Ohio Agr. Exp. Sta. Bul. 381, 1924.
[2]Jour. Am. Soc. Agronomy 16:68-73, 1924.

found to be less than 30 : 1 it is doubtful whether the difference is actually due to the treatment, and a definite fertilizer recommendation is not advanced upon such data.

The gross receipts are the actual returns from the produce when sold thru the Marietta Truck Growers' Association, with no deductions for cost of production, packages, or cartage. In the terminology of the Association they are "net receipts." The vegetables were graded when harvested, so that the receipts reflect the grade and the earliness as well as the yield. The increase in returns from the fertilizers was derived by the same arithmetical steps as used in calculating the increase in yield. The increase in income was then obtained by simply subtracting the cost of the fertilizer from the increase in returns. Any extra costs involved in harvesting and packing the increased yields were not deducted in these calculations of increased income.

Fertilizer costs have not changed materially since the preceding report (Bul. 377) and the costs applied to the first eight years' data have been used for the last four years:

Limestone	$ 5.00 per ton
Manure	3.75 per ton
Superphosphate (acid phosphate), 16 percent	20.00 per ton
Nitrate of soda, muriate of potash, and sulfate of ammonia, each	60.00 per ton

An adequate discussion of the financial aspects would necessitate some consideration of price fluctuations together with the effect of fertilizers on the quality of the produce. As it has not appeared advisable to enter into such details at this time, the emphasis here is on the increases in total yields due to the fertilizers, rather than on the financial income.

PROGRESS REPORTS

In the early years of this experiment, brief reports of the annual yields were included in Bulletins 303, 324, 344, and 361. At the close of the eighth year, Gourley and Magruder presented a more comprehensive analysis of the results in Bulletin 377. This was the first of a proposed series of quadrennial reports. The present bulletin is the second of this series.

FERTILIZER REQUIREMENTS OF EACH CROP

In the large tables, 23-30, of the appendix the averages of the first eight years and the last four years for each treatment are tabulated for each crop. In the present section the results from the various fertilizers are compared for the purpose of deriving recommendations applicable to the Marietta district. In following sections some generalizations of wider significance are discussed.

CABBAGE

See Tables 23 and 24

The high yields and large profits from early cabbage have been obtained from plots receiving lime and manure, or lime and heavy fertilizer treatment. In some instances in series B, where the check plots were not limed, the yield was more than doubled by lime and manure.

Lime on acid soils is generally conceded to be essential for maximum yields of cabbage. The increases from the use of limestone in the present experiment are shown in Table 1. The difference disclosed between the effect of limestone in conjunction with manure and in conjunction with chemical fertilizers may be explained by the fact that manure itself had a neutralizing effect reducing the acidity from pH 5.6 to 6.3, whereas the chemicals had no such effect.

TABLE 1.—Increases in Yield of Cabbage From Liming

Average annual increase in pounds per acre, 4 years, 1923-1926

Plot	Annual treatment	Increase over checks	Increase due to addition of limestone
33	Limestone only	3,630	3,630
24	Manure	12,235	
25	Manure and limestone	13,252	1,017
30	Chemical fertilizer	7,007	
31	Chemical fertilizer and limestone	9,783	2,776

Because of the importance of soil reaction to cabbage, it must be kept in mind that all plots of series A are limed. In the following discussion of fertilizers the comparisons are restricted to limed plots.

Nitrogen fertilizers increased the yield in every instance, irrespective of the kind of fertilizer or the combination in which it was applied, as shown in Table 2. The table shows incidentally that phosphoric acid was also a limiting factor on this soil—nitrate of soda plus superphosphate gave higher yields than nitrate of soda alone.

It is rather surprising to find in the last of these tabulated comparisons that nitrate of soda gave a large increase in yield when supplementing 16 tons per acre of manure. Evidently cabbage requires a large amount of nitrogen fertilizer on this soil. The highest yield in series A was on Plot 8, which received the largest amount of nitrogen used here, 480 pounds of nitrate of soda in a complete fertilizer. Perhaps more than this amount in a chemical fertilizer could be profitably used on this soil.

TABLE 2.—Increase in Yield of Cabbage From Nitrogen Fertilizers

Average annual increase in pounds per acre, 4 years, 1923-1926. All plots limed

Plot	Annual treatment	Increase over checks	Increase due to addition of nitrogen
12	Sulfate of ammonia	1,657	1,657
15	Nitrate of soda	1,517	1,517
11	Superphosphate	943	
9	Superphosphate and nitrate of soda	4,003	3,060
36	Superphosphate	4,810	
34	Superphosphate and nitrate of soda	9,640	4,830
28	Manure and superphosphate	12,893	
26	Manure, superphos., and nitrate of soda	17,029	4,136

Phosphoric acid, applied as superphosphate alone, or in a fertilizer mixture, consistently increased the average yield of cabbage. The results from supplementing manure were inconsistent and statistically insignificant. In the various fertilizer combinations there were no comparisons of different amounts of superphosphate, consequently it is impossible to determine directly the amount necessary for high yields. The large returns from the heavy application on Plot 8 suggest that this complete fertilizer, carrying 1200 pounds per acre of superphosphate, is excellently adapted to early cabbage. On the other hand, the fact that supplementing

TABLE 3.—Increases in Yield of Cabbage From Superphosphate

Average annual increase in pounds per acre, 4 years, 1923-1926

Plot	Annual treatment	Increase over checks	Increase due to addition of superphosphate
11	Superphosphate	943	943
33	Lime	3,630	
36	Lime and superphosphate	4,810	1,180
15	Nitrate of soda	1,517	
9	Nitrate of soda and superphosphate	4,003	2,486
3	Manure	3,413	
2	Manure and superphosphate	3,967	554
25	Manure	13,252	
28	Manure and superphosphate	12,893	—359

manure with superphosphate did not appreciably increase the yield, indicates that the phosphate fertilizer requirement of the cabbage crop on this soil is relatively low. Manure is low in phosphoric acid; 16 tons contains about the same amount as 400 pounds of 16 percent superphosphate. The large applications of chemical mixtures used here appear therefore to be unnecessarily high in phosphoric acid.

Potash had little, if any, effect on the yield of cabbage. On Plot 31, for instance, which received potash, the increase in yield was not significantly greater than on Plot 34 which did not receive potash. The largest increase attributable to potash was on Plot 6 where the average increase over the checks was 930 pounds per acre greater than that from Plot 9. An increase of 930 pounds was, however, less than 4 percent of the total yield. The odds are only 5.4:1 that the increase was actually due to the potash. In comparison with the results obtained from nitrogen and phosphoric acid, the effects of potash were of little significance.

If larger amounts of the other fertilizer constituents were used, potash might become a limiting factor, but from the data at hand little, if any, potash should be recommended in a chemical fertilizer for cabbage on this soil.

Manure.—Neither manure alone (Plot 3) nor manure supplemented with superphosphate (Plot 2) gave as large a yield of cabbage as the complete fertilizer on Plots 6 and 8. In this respect cabbage is peculiar; it is the only crop in the rotation that for the last four years gave better yields from chemicals than from manure. This peculiarity may be due to the fact that early cabbage makes most of its growth during the cool weather of early spring, when the chemical fertilizers are probably more readily available than the nutritive elements in manure; whereas, the others are warm-weather crops, which make most of their growth after the soil has become warmed and decomposition of manure in the soil is proceding more rapidly.

From the fact that the chemical fertilizer of Plot 6, supplying 50 pounds of nitrogen, gave higher yields than 16 tons of manure (Plots 2 or 3) it may be concluded that the manure was supplying to the cabbage less than 3 pounds of available nitrogen per ton. This, together with the fact that nitrate added to manure gave a marked increase in yield, leads to the conclusion that the failure of manure to give maximum yields of early cabbage was due to the lack of availability of large portions of its nitrogen during the early spring.

With manure costing $3.75 per ton, it obviously is not an economical fertilizer for early cabbage. Nitrate of soda, costing $14.40, applied to Plot 14, gave higher yields than 16 tons of manure per acre on Plot 3. From this comparison, manure had a value of less than 90 cents per ton. Even if it could be obtained in large quantities at this price, it would clearly be advisable to supplement it with a chemical nitrogen fertilizer, as was done in the present experiment on Plot 26.

Summary and recommendation.—On this acid soil (pH about 5.6) liming was beneficial to cabbage.

Nitrate of soda in combination with either superphosphate or manure gave large increases in yield. A complete fertilizer containing 480 pounds of nitrate of soda (75 pounds of nitrogen) gave a higher yield than a smaller amount of the same mixture. At least 75 pounds of nitrogen is therefore recommended as a component of a fertilizer mixture.

Phosphoric acid fertilizer was also essential for high yields. Direct comparisons of various amounts are lacking, but the fact that supplementing manure with superphosphate did not increase the yield indicates that the phosphoric acid requirement was equivalent to about 400 pounds of 16 percent superphosphate per acre.

Potash fertilizer has not as yet had a significant effect on the average yield of cabbage in the comparisons of this experiment.

Manure applied at the rate of 16 tons per acre did not produce as high yields as chemical fertilizers. By supplementing manure with nitrate of soda excellent yields resulted. Manure was not as econmical for early cabbage as some of the mixed chemical fertilizers.

TOMATOES

See Tables 25 and 26

Tomatoes, like cabbage, gave a large response to fertilizers, some of the fertilized plots yielding about double that of the untreated checks.

Lime, however, had relatively little effect on tomatoes. Alone, as on Plot 33, lime produced a small average increase. With manure on Plot 25 lime gave an increase the first eight years and a small decrease the last four years. The increase due to lime on Plot 31, which received chemical fertilizers, was 891 pounds per acre during the last four years, but oddly the returns were less from this plot than from the adjacent unlimed Plot 30. Apparently the maturity was retarded or the quality lowered by the use of limestone in connection with the chemical fertilizer. There is nothing in these figures to encourage the use of limestone with either manure or chemical fertilizers.

Nitrogen fertilizers, whether applied alone or in combination with other constituents, increased the average yield of tomatoes, as shown in Table 4. Even the addition of nitrate of soda to 16 tons of manure per acre gave an increase in yield the last four years. This unexpected result, however, was not obtained during the first eight years, hence supplementing manure with nitrogen fertilizer can hardly be recommended from the data at hand. It is known that an abundance of soil nitrogen may stimulate excessively vegetative growth in the tomato plant at the expense of the fruit. An excess of nitrogen fertilizer is therefore to be avoided.

TABLE 4.—**Increases in Yield of Tomatoes From Nitrogen Fertilizers**

Average annual increase in pounds per acre, 4 years, 1923-1926

Plot	Treatment	Increase over checks	Increase due to addition of nitrogen
15	Nitrate of soda	668	668
12	Sulfate of ammonia	78	78
11	Superphosphate	1,065	
9	Superphosphate and nitrate	1,425	360
36	Superphosphate	80	
34	Superphosphate and nitrate	2,044	1,964
28	Manure, superphosphate	6,188	
26	Manure, superphosphate and nitrate	7,239	1,051

The yield of tomatoes from 1830 pounds per acre of a 4-10-4 combination on Plot 8 was not as large as from 1220 pounds of the same mixture on Plot 6. The fertilizer of Plot 6, supplying about 50 pounds of nitrogen per acre, gave higher yields than any other combination, and nearly as good yields as the manured plots of series A. About 50 pounds of nitrogen in a fertilizer thus appears to be sufficient for the early crop as grown on this soil.

Superphosphate, whether used alone or supplementing other fertilizers, in all but one instance gave an increase in average yield of tomatoes. The one exception is of little significance because it occurred on Plot 36 at the edge of the field where an accurate comparison with a check was impossible.

Altho phosphoric acid is clearly essential, the amount required cannot be accurately determined. The phosphoric acid in 16 tons of manure per acre (about 64 pounds) was inadequate as evidenced by a 4 percent increase in yield when the manure was supplemented with superphosphate. This 4 percent increase is statistically significant when the entire 12 years of the experiment are taken into consideration. Plot 28, receiving a superphosphate supplement, outyielded Plot 25, 9 years out of 12, giving odds of 17:1 that the difference was not due to chance. The comparison of Plots 2 and 3 is more convincing, for here the odds are 241:1 that the difference is due to the supplement. The tomato crop thus required more phosphoric acid than the 64 pounds per acre supplied by the manure.

Experiments elsewhere have also emphasized the importance of phosphoric acid to tomatoes, and, as it is the cheapest of the fertilizer constituents, a liberal application is generally recommended and used. For conditions similar to those at the Washington County Truck Farm somewhat more than 64 pounds of phosphoric acid per acre in a complete fertilizer is therefore recommended for tomatoes.

TABLE 5.—Increases in Yield of Tomatoes From Superphosphate

Average annual increase in pounds per acre, 4 years, 1923-1926

Plot	Treatment	Increase over checks	Increase due to addition of phosphate
11	Superphosphate	1065	1065
33	Lime only	134	
36	Lime and superphosphate	80	—54
15	Nitrate	668	
9	Nitrate and superphosphate	1425	757
3	Manure	3655	
2	Manure and superphosphate	3912	257
25	Manure	5403	
28	Manure and superphosphate	6188	785

Potash.—During the first 8 years, potash had no significant effect on yield of tomatoes, but during the last 4 years, Plot 6, receiving muriate of potash, outyielded Plot 9 by 1765 pounds per acre. Similarly, the complete fertilizer of Plot 31 gave higher yields than the nitrate and superphosphate of Plot 34. A potash deficiency thus appears to be developing under the current system of culture. A complete fertilizer carrying 100 pounds of muriate of potash per acre, Plot 6, gave as good results as the heavier applications of the same fertilizer mixture on Plot 9, indicating that 100 pounds of muriate of potash annually was ample for the tomato crop during the past four years.

Manure, particularly when supplemented with superphosphate, gave larger yields of tomatoes than any of the chemical fertilizers. But at the current price ($3.75 per ton) it was not as profitable in series A as the complete chemical fertilizers of Plots 6 and 8.

Superphosphate was beneficial as a supplement to manure. The increase in yield, however, was only 4 percent, suggesting that relatively small amounts were needed with 16 tons of manure.

Summary and recommendation.—Lime had but little effect on tomatoes on this soil.

A nitrogen fertilizer was essential for high yields where no manure was used. A complete fertilizer supplying about 50 pounds of nitrogen gave better results than a heavier application of the same mixture. About 50 pounds of nitrogen per acre, therefore, is recommended as a constituent of a complete fertilizer for tomatoes on this soil.

Phosphoric acid fertilizer was also essential. The treatments do not admit of comparisons of different amounts in chemical combinations, but the fact that supplementing manure was profitable leads to the conclusion that more than 400 pounds of 16 percent superphosphate (64 pounds of phosphoric acid) would be required in a chemical fertilizer.

During the past four years, potash fertilizer also increased yields. There was no indication that large amounts were required; 100 pounds per acre of muriate of potash (50 pounds K_2O) appeared to be ample, possibly less would have sufficed.

A complete fertilizer for tomatoes then would include all three constituents. As phosphoric acid is the cheapest, and as experiments elsewhere have emphasized its importance to early yields, in practice a liberal amount should be applied. A liberal application might be 100 pounds of phosphoric acid per acre, an amount obtained in 1000 pounds per acre of a 5-10-5 fertilizer. It is possible that a combination carrying somewhat less potash would be adequate.

Manure gave excellent yields of tomatoes. A supplement of superphosphate further increased the yield. At a cost of $3.75 per ton, however, 16 tons of manure per acre was not as profitable as a complete chemical fertilizer.

CUCUMBERS

See Tables 27 and 28

Cucumbers, like cabbage and tomatoes, gave a large response to fertilizers. The outstanding peculiarity of the cucumber crop was its marked response to manure and to nitrogen fertilizers. Cucumbers profitably used more nitrogen than any other crop of the rotation.

Before proceding to the analysis of the data, some of the difficulties encountered in conducting field experiments with cucumbers need to be pointed out. Cucumber plants are frequently injured by insects and diseases, particularly during the early stages of growth. At harvest, more or less injury to the vines is unavoidable. Such set-backs to the plants introduced large variations from plot to plot in the present experiment that clearly were not due to the fertilizer treatments. The experimental errors with cucumbers were, therefore, larger than with the other crops of the rotation and the data are correspondingly difficult to interpret.

Lime alone (Plot 33) or with chemicals (Plot 31) had little effect on yield; the averages of the last four years showed a small reduction from the lime. With manure (Plot 25) the yield was slightly increased. From the results to date, lime is not recommended for cucumbers on this soil.

Vigorous growth of cucumbers at left on manured plot. Unfertilized plot at right

Nitrogen.—The averages of the last four years showed a small increase from nitrate of soda when used alone (Plot 15), and a decrease from sulfate of ammonia (Plot 12). Neither of these results, however, was of much significance, because phosphoric acid deficiency was a limiting factor. As both phosphoric acid and nitrogen deficiencies were limiting factors in cucumber yields, neither constituent alone gave a marked increase, but together the increase averaged nearly 4000 pounds per acre (Plot 9).

Manure gave larger yields of cucumbers than did any of the chemical fertilizers used here, which may be partly or wholly due to the fact that 16 tons of manure per acre supplied about 160 pounds of nitrogen, whereas the largest application of chemicals supplied only 75 pounds. That cucumbers require a large amount of nitrogen is illustrated by the 6000 pounds difference between Plots 25 and 28 resulting from the addition of 160 pounds of nitrate of soda per acre to manure. Even with this large amount of nitrogen there was no indication that the upper limit of profitable application was reached.

Phosphoric acid fertilizer, as just mentioned, was essential for satisfactory cucumber yields. But unlike nitrogen, relatively small amounts appeared to be adequate. The phosphoric acid supplied in 16 tons per acre of manure, which is equivalent to about 400 pounds of 16 percent superphosphate, was sufficient, as shown by the fact that Plot 28 receiving superphosphate in addition to manure did not appreciably differ in yield from Plot 25. A similar conclusion may be drawn from a comparison of the yields of Plots 2 and 3. The phosphoric acid requirement in a chemical fertilizer cannot be definitely determined from the data at hand, but, judging from these results with manure supplements, the requirement of the crop on this soil does not exceed the equivalent of 400 pounds per acre of 16 percent superphosphate.

Potash gave variable increases in yield, which were peculiarly difficult to interpret. Plot 6, receiving a complete fertilizer during the last four years, averaged only 285 pounds of cucumbers per acre more than Plot 8, which is not a significant difference. During the same period Plot 31 averaged 4381 pounds per acre more than Plot 34. The latter comparison was probably not a true measure of the effect of potash, because the calculated increase of Plot 34 was partly based on an abnormally low yield of check Plot 35. The first comparison is therefore more reliable, and leads to the conclusion that potash deficiency has not as yet became a significantly limiting factor to cucumbers in this experiment.

Manure.—The largest yields and the largest incomes with cucumbers were from manured plots. The excellent yields may in part be attributed to the large amount of nitrogen in manure. Unfortunately, it is impossible to say to what degree the yields were due to available nitrogen, for none of the chemical treatments supplied as much as the manure. In part, the results may have been due to more favorable physical condition of the soil of the manured plots.

These large yields in comparison with yields from chemicals give manure a high value as a fertilizer for cucumbers. If the manure applied to Plots 2 and 3 had cost $5 per ton, the increase in income would still have been greater than from the most profitable of the chemical treatments (Plot 6).

TABLE 6.—Comparison of Cucumber Yields From Manure and From Complete Fertilizers

Average annual increase over unfertilized checks in pounds per acre, 4 years, 1923-1926

Plot No.	Treatment per acre	Increase
Series A		
6	1220 pounds complete fertilizer	4,167
8	1830 pounds complete fertilizer	4,923
3	Manure 16 tons	7,148
5	Manure 20 tons	7,958
Series B		
30	610 pounds complete fertilizer	5,187
27	Manure 16 tons	14,908
24	Manure 16 tons	15,500

Where manure was applied at the rate of 20 tons per acre, the yield was further increased but not at a further profit.

In conclusion, then, if manure is available in limited quantities, it can be applied more profitably to cucumbers than to any of the other crops. Supplementing 16 tons per acre with nitrate of soda was also profitable.

Summary and recommendation.—Lime produced no significant effect on the yield of cucumbers on this soil.

In the study of chemical fertilizers, both nitrogen and phosphoric acid were found to be essential. Nitrate of soda gave conspicuous increases in yield, when used either as a component of a chemical fertilizer or as a supplement to manure. These results from nitrate of soda indicated a very high nitrogen requirement for the cucumber crop. At least 75 pounds per acre of nitrogen would be recommended from the data at hand, and possibly two or three times this amount could be profitably used. However, an application of 150 to 200 pounds of nitrogen in a readily soluble fertilizer, such as nitrate of soda, would mean the use of 1000 pounds or more per acre, which cannot be unreservedly recommended, for there is the danger of producing too high a concentration of soluble salts in the soil.

Direct comparisons of various amounts of superphosphate from which a recommendation might be derived are lacking. From the fact that manure did not need a phosphate supplement, it is concluded that 64 pounds of phosphoric acid (400 pounds of 16 percent superphosphate) would be sufficient for the cucumber crop on this soil.

The results from the use of potash fertilizer are difficult to interpret, but the conclusion drawn at this time is that potash has not significantly affected the yield.

The manure gave higher yields than any of the chemical treatments. The addition of nitrate of soda further increased the yield.

SWEET CORN

See Tables 29 and 30

In contrast to the other crops, sweet corn gave but small response to fertilizers. On corn the increases were 20 to 30 percent from heavy fertilization; on the other crops the yields were frequently doubled by the same treatments. The results were even more conspicuous in the income. With corn most of the treatments resulted in losses. The largest average increase in income was only $22.43; with the other crops the increase due to fertilizers frequently exceeded $100 per acre.

The low returns from sweet corn were due in part to the fact that the crop has the lowest per acre value of any in the rotation. The gross returns from corn averaged less than $200 per acre, while the other crops averaged two or three times this amount. Moreover, following the system of spacing the hills 36 by 34 inches, the yield of 3½ tons, which was obtained from the unfertilized plots, was considered a fair crop. Unpublished results from a spacing experiment show that the yields may be raised by closer spacing of the hills. Closer spacing would result in a larger draft upon the soil nutrients, and under such conditions larger increases from fertilizers would be expected than have been obtained here.

Lime alone was beneficial to sweet corn. In conjunction with chemical fertilizers or with manure the effect of lime was small and not statistically significant.

Nitrogen fertilizers alone, or with superphosphate, gave profitable increases in the average yields. Sulfate of ammonia alone on Plot 12 was more profitable than any other treatment. This plot receives only 260 pounds per acre. The larger yields from manure indicate that more than this amount of nitrogen could be profitably used. This is speculative, however, and in view of financial losses resulting from the use of manure and the relatively small increased income from the sulfate of ammonia, larger amounts can hardly be recommended.

Superphosphate unexpectedly, but consistently, depressed the average yield of all plots to which it was applied. There is nothing in the table of comparisons to justify the use of superphosphate on sweet corn under the conditions of this experiment. The writers have no explanation to suggest for this unexpected result.

TABLE 7.—Effect of Superphosphate on Yield of Sweet Corn

Average annual increase or decrease in pounds per acre, 4 years, 1923-1926

Plot	Treatment	Increase over checks	Increase due to addition of superphosphate
11	Superphosphate only	167	—167
33	Lime only	273	
36	Lime and superphosphate	270	—3
15	Nitrate of soda	1,083	
9	Nitrate of soda and superphos.	387	—696
3	Manure	1,473	
2	Manure and superphosphate	1,317	—156
25	Manure	3,831	
28	Manure and superphosphate	3,502	—329

Potash produced small increases in yield. A comparison of Plots 31 and 34 shows an increase due to potash of 163 pounds per acre. Likewise, Plot 6, receiving a complete fertilizer, outyielded Plot 9 by 326 pounds per acre. These increases are, however, of doubtful significance (see page 25) and hardly justify recommending the use of potash for sweet corn on this soil.

Manure gave higher yields than any of the chemical fertilizers, but the returns did not cover the cost. Manure furnished larger amounts of both nitrogen and potash than any of the chemical combinations, and at the same time added but little of the detrimental phosphoric acid. The proportion of the fertilizer constituents in manure is thus better adapted to sweet corn on this soil than the proportion in the complete fertilizers.

As a commercial practice, manure cannot be used for sweet corn at the price and in the quantities used here. At a lower price limited amounts might be profitable, but at Marietta the profit would be insignificant when compared to the returns from manuring cucumbers or tomatoes.

Summary and recommendation.—From the viewpoint of yields alone, without reference to profit, manure gave the best results with sweet corn.

The only chemical fertilizer that can be recommended from these data for sweet corn is one supplying nitrogen. Superphosphate depressed yields. Neither lime nor potash gave increases large enough to justify recommending its use.

If the hills had been closer than 36 by 34 inches, the sweet corn would doubtless have made a larger drain on the soil nutrients, and probably fertilizers would have been more profitable.

SPECIAL STUDIES ON NITROGEN FERTILIZATION

As nitrogen is the most expensive of the three principal fertilizer constituents as well as the most important limiting constituent on this soil, two special studies with nitrogen were included in the experiment. The first was a comparison of the results from delaying one-half of the application of nitrate of soda until after the plants were established; the second a comparison of sulfate of ammonia with nitrate of soda. In both of these comparisons no fertilizer other than the nitrogen carriers was used, consequently phosphoric acid deficiency was a complicating factor, making the results of doubtful significance.

Delayed application of nitrate of soda.—On all of the experimental plots, except Plot 14, the fertilizer was spread broadcast at the time of fitting the soil. On Plot 14, one-half of the application of nitrate of soda was withheld until the plants were well established. Comparing the yields of this plot with the adjacent Plot 15, there was a large benefit to cabbage from the delayed application and small benefits, probably not significant, to the other crops.

TABLE 8.—Effect of Delayed Application of Nitrate of Soda

Average annual yields in pounds per acre, 4 years, 1923-1926

	Time of application		Increase due to delayed application
	Prior to planting Plot 15	Half applied later Plot 14	
Cabbage	20,300	23,730	3,430
Cucumbers	12,400	13,075	675
Sweet corn	8,250	8,590	340
Tomatoes	7,760	8,035	275

The fact that all four crops produced as good or better yields from the delayed application as from the entire amount of fertilizer applied prior to planting may have special importance where readily soluble fertilizers are to be used in large amounts. Heavy application of soluble salts prior to planting introduces a danger from an excessive concentration of salts. Delaying the application of part of the nitrogen fertilizer until after the plants are established, in a measure, averts this danger.

Sulfate of ammonia vs. nitrate of soda.—At the time the experiment was started in 1915, nitrate of soda was deemed the best source of nitrogen for fertility studies. By 1922, however, sulfate of ammonia was as cheap a source of nitrogen as nitrate of soda, and experiments elsewhere had indicated that for many crops it was as efficient as nitrate. Hence, a comparison of equivalent amounts of these two carriers of nitrogen was started.

TABLE 9.—Comparison of Sulfate of Ammonia and Nitrate of Soda

Average annual increase over checks in pounds per acre, 4 years, 1923-1926. All plots limed

	Increase over checks		Higher yielding treatment	Increase	
	Plot 12 sulfate of ammonia	Plot 15 nitrate of soda		Pounds	Odds
Cabbage	1,657	1,517	Sulfate of ammonia	140	1:1
Tomatoes	78	668	Nitrate of soda	590	4:1
Sweet corn	1,387	1,083	Sulfate of ammonia	304	7:1
Cucumbers	—1,452	800	Nitrate of soda	2,252	1:1

The four-year average shows that nitrate of soda gave higher yields than sulfate of ammonia on tomatoes and cucumbers and lower yields on cabbage and sweet corn. The results, however, varied from year to year, so that the averages are not statistically significant. The odds being low, the evidence is not conclusive that either of these nitrogen fertilizers is superior to the other on any one of the four crops.

COMPARISON OF THE FOUR CROPS

Specific fertilizer recommendations derived from experiments at one place are necessarily limited to soil of that particular type and condition. Unless due consideration is given to commercial practices as well as to experiments elsewhere a general fertilizer recommendation for any crop cannot be advanced. Since a comprehensive literature review is beyond the scope of the present report, the specific deduction and recommendations for each crop presented in the preceding pages are of local rather than of general application. Facts of wider interest and broader application are to be found, however, in a comparison of the reaction of the different crops to the various fertilizer treatments.

In the present experiments each crop was grown each year and in a rotation, so that seasonal and soil variations were largely eliminated in drawing comparisons. The data are therefore of value in showing differences in the four crops.

RESPONSE TO CHEMICAL FERTILIZERS

Nitrogen fertilizers gave conspicuous increases in all of the crops, but particularly in cucumbers and cabbage. The relative increases in yield of each crop from the same amount of nitrate of soda are illustrated by a comparison of yields from Plot 11, which received only superphosphate, and Plot 9, which received nitrate in addition. Plot 11 is selected as a base for this comparison instead of the unfertilized checks in order to avoid complication from deficiency of phosphoric acid. As shown in Table 10, cucumbers gave a 36 percent increase from the nitrate of soda, cabbage about half this increase, and sweet corn and tomatoes much less. The addition of nitrate of soda to 16 tons of manure produced the same relative effect (Plots 26 and 28). Cucumbers and cabbage showed a much larger response to the supplement than did tomatoes or sweet corn.

TABLE 10.—Increase in Yield From Nitrate of Soda

Average annual increase in pounds per acre and percentage, 4 years, 1923-1926

	Average annual yield		Increase due to addition of nitrogen	
	Superphosphate only Plot 11	Superphosphate and nitrate of soda Plot 9	Pounds	Percent
Cucumbers	13,280	18,050	4770	35.9
Cabbage	20,240	24,040	3800	18.8
Sweet corn	7,040	7,640	600	8.5
Tomatoes	9,035	9,690	655	7.3

Phosphoric acid fertilizer produced a similar order of response. With tomatoes and sweet corn the effect of phosphoric acid may be illustrated by a conparison of the results from Plot 9 with those of Plot 15. With cucumbers and cabbage this comparison is not strictly accurate, for during the last four years these two crops received an extra amount of nitrate of soda on Plot 15. No better comparison is available, however. Table 11 shows that the per-

TABLE 11.—Increase in Yield From Superphosphate

Average annual increase in pounds per acre and percentage, 4 years, 1923-1926

	Yield from nitrate alone Plot 15	Increase of Plot 9 over Plot 15 due to addition of superphosphate	
		Pounds	Percent
Cucumbers	12,400*	3,082	24.8
Cabbage	20,300*	2,486	12.2
Tomatoes	7,760	757	9.8
Sweet corn	8,250	—696	—8.4

*Cucumbers and cabbage receive 480 pounds of nitrate of soda per acre on Plot 15 and 320 pounds per acre on Plot 9.

centage increases from superphosphate are much higher on cucumbers and cabbage than on tomatoes or sweet corn. The decrease from superphosphate on sweet corn was unexpected and is unexplained.

Potash deficiency has not become an important factor on this soil, hence no comparisons of real value can be drawn. During the first eight years of the experiment no significant effect from the use of muriate of potash was observed on any of the crops. During the last four years, particularly on series A, where the treatment was doubled, there was a definite increase in yield on tomatoes, but only on tomatoes. The data of the last four years for both series A and series B are given in Table 12 to show the magnitude of the increases.

TABLE 12.—Increase in Yield From Potash

Average annual increase in pounds per acre, 4 years, 1923-1926

Series A, comparing Plot 9, receiving annually 320 pounds of nitrate of soda and 800 pounds of superphosphate per acre, with Plot 6, receiving the same plus 100 pounds per acre of muriate of potash.

	Increase over checks		Increase due to addition of potash	
	Plot 9	Plot 6	Pounds	Odds
Tomatoes	1425	3190	1765	212.0:1
Cucumbers	3882	4167	285	2.7:1
Cabbage	4003	4933	930	5.4:1
Sweet corn	387	713	326	2.1:1

Series B, comparing Plot 34, receiving annually 160 pounds of nitrate of soda plus 400 pounds of superphosphate, with Plot 31, receiving the same plus 50 pounds of muriate of potash.

	Increase over checks		Increase due to addition of potash	
	Plot 34	Plot 31	Pounds	Odds
Tomatoes	2044	2958	914	12.1:1
Cucumbers	687	5068	4381	102.0:1
Cabbage	9640	9783	143	1.5:1
Sweet corn	1107	1270	163	2.7:1

The significant increase on cucumbers in series B was in part due to an unexplained, abnormally low yield on Plot 34. The very small increase in series A probably represents more nearly the true reaction of the cucumbers to potash on this soil. The conclusion, then, is that only on the tomatoes in series A was potash significantly beneficial.

Lime was distinctly beneficial to cabbage. The unlimed soil was moderately acid, having a pH about 5.6. Ground limestone, applied annually at the rate of one ton per acre made the soil neutral or slightly alkaline, pH 7.0 to 7.2. Tomatoes and sweet corn showed significant increases where the limestone was used alone, but in conjunction with either manure or chemicals the increase was insignificant (Table 13). These benefits from limestone alone possibly were due to the increase in the growth of the soybean cover crop and consequent increase in the nitrogen and organic matter of the soil. Under practical conditions, where soil fertility is maintained by the use of either manure or chemicals, there is no indication in these data that liming would be profitable on corn, tomatoes, or cucumbers. On the other hand, if lime were used to maintain the yield of cabbage in a rotation, there is no evidence here that the residual effect of the lime would be a detriment to the other crops.

TABLE 13.—Increase in Yield From Liming

Average annual increase due to ground limestone on unfertilized Plot 33, on manured Plot 25 (compared with 24), and on chemically fertilized Plot 31 (compared with Plot 30). Pounds per acre, 12 years, 1915-1926

	Limestone alone		With manure		With chemical fertilizer	
	Increase due to lime	Odds	Increase due to lime	Odds	Increase due to lime	Odds
Cabbage	3,032	∞:1	792	∞:1	1,972	525:1
Sweet corn	698	1666:1	396	15:1	7	<1:1
Tomatoes	459	137:1	274	5:1	340	4:1
Cucumbers	—10	<1:1	1,838	19:1	—212	2:1

Summary.—The percentage increases condensed into a summary table illustrate the differences in the response of the four crops to the various nutritive elements. Table 14 shows the similar order of response to nitrogen and phosphoric acid. Cucumbers gave a large increase from both; cabbage gave about half the response shown by cucumbers; and tomatoes and sweet corn much less. Potash produced a significant increase on tomatoes only.

TABLE 14.—Increase From Initial Application of Each Fertilizer Constituent

	Nitrogen	Phosphoric acid	Potash*
	Pct.	*Pct.*	*Pct.*
Cucumbers	36	25	2
Cabbage	19	12	4
Tomatoes	7	10	18
Sweet corn	9	—8	4

*Calculated from comparison of Plots 6 and 9.

In a sense these percentages are an expression of the importance of each constituent as a limiting factor on this soil. As far as the data permitted, the percentages were calculated to show the increase in yield from each constituent when the other limiting constituents were present. For instance, the percentage increase from nitrogen was computed from plots receiving superphosphate as a basic treatment. Where potash was a limiting factor, as in the case of tomatoes, this method could not be strictly followed, for there was no plot receiving phosphoric acid and potash to serve as a basic treatment from which to determine the effect of added nitrogen. Consequently, the calculated percentage increases from either nitrogen or phosphoric acid on tomatoes are probably depressed by the deficiency of potash, and the increase from potash may be higher than its relative importance as a limiting factor. In spite of these limitations of the data, characteristic differences are evident in the response of the four crops to the various fertility constituents. These results, it must be kept in mind, are from plots which have been well limed.

A similar illustration of the characteristic differences in the crops is found in a comparison of the various amounts of fertilizers recommended for each. Comparing Table 15 with the preceding table one finds an interesting correlation between the initial response and the amount of each constituent recommended.

TABLE 15.—Relative Amounts of Fertilizer Constituents Recommended For Each Crop in Pounds per acre

	Nitrogen	Phosphoric acid	Potash
Cucumbers	75+	64	0
Cabbage	75	64	0
Tomatoes	50	64+	50—
Sweet corn	50	0	0

RESPONSE TO MANURE

In view of the decreasing supply of manure, interest centers not so much upon crop response to large amounts as upon economy in its use and its value in comparison with chemical fertilizers. The increases in yield from manure will therefore be treated briefly.

Cucumbers gave much larger increases in yield from manure than sweet corn or cabbage. Tomatoes stood second in order of response. The percentage increases from 16 tons of manure per acre, Table 16, were much larger on series B than on series A, due in part to the lower state of fertility of the unfertilized plots of series B. The order of response of the four crops, however, was essentially the same in both series.

TABLE 16.—Increase From 16 Tons of Manure Per Acre

Average annual increase from manure and lime over plots receiving lime only in pounds per acre and percentage, last four years, 1923-1926

	Series A Increase of Plot 3, manure, over checks*		Series B Increase of Plot 25, manure and lime, over Plot 33, lime alone	
	Pounds	Percent	Pounds	Percent
Cucumbers	7,148	44.9	17,763	206.1
Tomatoes	3,655	41.3	5,269	85.1
Sweet corn	1,473	18.5	3,558	54.7
Cabbage	3,413	17.5	9,622	55.8

*All plots of series A are limed.

The application of 20 tons of manure per acre to Plot 5 during the last four years has not as yet produced a significant increase over the standard 16-ton application. The increase due to the additional 4 tons has been more consistent on cabbage and corn than on cucumbers and tomatoes, as shown by the odds in Table 17; but the comparison has been carried on for only four years and none of the increases are statistically significant. There is therefore very little support in these data for the use of more than 16 tons of manure per acre.

TABLE 17.—Comparison of 20 and 16 Tons of Manure Per Acre

Average annual increase over unfertilized checks in pounds per acre, 4 years, 1923-1926

	16 tons Plot 3	20 tons Plot 5	Increase due to additional 4 tons of manure	
			Pounds	Odds
Sweet corn	1,473	1,917	444	21.9:1
Cabbage	3,413	4,157	744	13.2:1
Cucumbers	7,148	7,958	810	1.9:1
Tomatoes	3,655	3,552	—103	1.5:1

VALUATION OF MANURE

Where manure is available in limited quantities at a high price, an important practical question is its relative value for different crops.

Manure varies widely in its composition depending upon the feeding and care of the animals, the nature and amount of bedding used, and upon the amount of weathering to which it has been exposed. These factors must be considered in interpreting field results and appraising the value of any particular lot of manure.

In the present experiments, the manure has been purchased from city stables; probably no special care was given to preserve it and in shipping and handling it was exposed to more or less weathering. Judging from laboratory analyses of partially weathered manure[3] it would probably contain at least 10 pounds of nitrogen, 4 pounds of phosphoric acid, and 10 pounds of potash per ton. These constituents in a commercial fertilizer would cost about $2.82 at Marietta.

When the value of manure is determined from the yields obtained in comparison with the yields obtained from chemicals very different values are found. On cabbage and sweet corn, for instance, the increase from manure has been relatively small; the yields of these two crops from 16 tons of manure on Plot 3 were about the same as the yield from the nitrate of soda on Plot 14. As the nitrate of soda of Plot 14 cost but $14.40 per acre for the cabbage and $9.60 for the corn, the comparative value of 16 tons of manure per acre was about 90 cents per ton on cabbage and only 60 cents per ton on sweet corn.

At the other extreme, on both cucumbers and tomatoes the manured plots outyielded the large applications of chemicals. Direct comparisons are therefore impossible. On cucumbers the average increase of income from manure (Plot 3) was $132.17, while the average from the best chemical treatment (Plot 6) was only $110.37. A simple calculation shows that if the manure applied to Plot 3 had cost $5.11 per ton, the increase in income would have been $110.41, essentially the same as that from the chemical fertilizer of Plot 2. On the basis of this comparison, manure at a cost of $5.11 per ton would be as economical a source of fertility for cucumbers as any of the chemical combinations used in this experiment.

This figure of $5.11 per ton, however, cannot be taken as an exact value in comparison with chemicals, for, as has been repeatedly emphasized here, the chemical treatment with which manure is compared is doubtless too low in nitrogen for best results with cucumbers A complete chemical fertilizer higher in nitrogen would be expected to give a larger profit than has Plot 6 and at a relatively low cost, and in consequence the comparative value of manure would be lower.

In practical production it is obvious that if manure is available in limited quantities it should be applied to cucumbers rather than to the other crops. Judging from the excellent results from

[3]Ames and Gaither, Bul. 246, Ohio Exp. Sta., 1912.

manure on cucumbers, a conservative practice to follow would be to use some manure, even at a cost of $5 per ton, liberally supplementing with a chemical fertilizer. This suggestion is advanced because of the indication that manure may be of value to cucumbers aside from the chemical nutrients supplied, and also because a very large application of soluble nitrogen fertilizer, such as appears to be required by cucumbers, might lead to some detrimental effect from the high concentration of salt.

Likewise with tomatoes the yield has been greater from manure than from chemicals, suggesting that manure may have some value aside from the nutrients supplied by chemicals. But with tomatoes, manure at $3.75 per ton was not as profitable in this experiment as the chemical fertilizer of Plot 6. The cost of manure would have to be reduced to $2.98 to give an increase in income equal to that obtained from Plot 6. The use of manure on tomatoes would therefore be largely governed by its cost.

To summarize, the valuations of manure when applied at the rate of 16 tons per acre in comparison with chemical treatments used here are:

On cucumbers	$5.11
On tomatoes	2.98
On cabbage	.90
On sweet corn	.60

These appraisals are based on the valuation of chemical fertilizers as given on page 9. With fluctuations in the value of chemicals, particularly nitrogen fertilizers, the value of manure would also fluctuate. The value of manure varies with its quality. Moreover, it is probable that smaller amounts might be used with greater relative profit, but evidence on this point is not at hand. The main point in deriving these values is not the actual figures themselves since they vary with so many factors, but the striking difference in the value of manure on the four crops.

MAINTENANCE OF YIELDS WITHOUT MANURE

At the beginning of these experiments the soil had been depleted by previous cultivation and was in a low state of fertility. Practically all of the fertilizer treatments, therefore, have given increased yields during the course of the work. As a matter of fact, the use of cover crops alone on the unfertilized plots produced higher yields the last four years than during the early years of the experiment. From the practical viewpoint, these increases are of interest as an illustration of success in bringing a run-down soil back into commercial truck crop production.

In dealing with the maintenance of fertility, the problem of most importance is whether satisfactory yields can be maintained by the use of chemical fertilizers together with cover crops without animal manure. Since years of practical gardening experience have demonstrated that high yields of vegetables may be maintained for indefinite periods by the liberal use of manure, manured plots may be taken as a standard with which to compare the results from chemical fertilizers. In drawing a comparison from the present work it must be kept in mind that the manured plots received 16 tons per acre annually, while the chemically fertilized plots received no manure during the entire course of the experiment.

During the first eight years a direct comparison was possible between the manure of Plot 5 and a fertilizer treatment equivalent to 1220 pounds per acre of 4-10-4 on Plot 6. The comparison of the average yields as given in Table 18 discloses insignificant differences on all crops except cabbage, and on cabbage the chemicals produced 1,500 pounds per acre more than manure. As a whole, then, during the first eight years, yields were maintained by chemicals as well as by manure.

TABLE 18.—Comparison of 16 Tons of Manure Per Acre With 1220 Pounds of 4-10-4 Fertilizer

Average annual yield, in pounds per acre, first 8 years, 1915-1923

	Manure Plot 5	Chemicals Plot 6	Difference in favor of manure
Sweet corn	8,290	8,115	175
Tomatoes	13,255	13,138	117
Cucumbers	19,549	19,619	—70
Cabbage	19,400	20,900	—1500

During the last four years, however, differences in favor of manure have developed. It is only with cabbage that the chemicals have outyielded the manure. Due to changes in the plans of applying fertilizer, direct comparisons between contiguous plots are not available for this period, but the increases from the chemical treatment of Plot 6 may be compared with those from the 16-ton treatment of Plot 3. The comparison discloses a large difference in favor of manure on cucumbers, smaller differences on tomatoes and corn, and better results from chemicals on the cabbage (Table 19).

The changes in plan in 1923 included a number of increases in the chemical treatments and an increase in the manure of Plot 5 to 20 tons per acre. An interesting comparison is therefore available between the larger applications of both manure and chemicals. An

TABLE 19.—Comparison of 16 Tons of Manure Per Acre With 1220 Pounds of 4-10-4 Fertilizer

Average annual increase over unfertilized checks in pounds per acre last 4 years, 1923-1926

	Manure Plot 3	Chemicals Plot 6	Difference in favor of manure
Cucumbers	7148	4167	2981
Tomatoes	3655	3190	465
Sweet corn	1473	713	760
Cabbage	3413	4933	—1520

examination of the results from the chemical treatments shows, however, that the largest fertilizer application, the 1830 pounds per acre of 4-10-4 on Plot 8, did not give as large yields of either tomatoes or corn as some of the lighter treatments. In drawing a comparison, therefore, not the heaviest but the highest-yielding chemical treatment is compared with the 20-ton application of manure. This comparison, Table 20, shows essentially the same relation as the preceding table: a large difference in favor of manure on cucumbers, small differences on tomatoes and corn, and a higher yield from chemical fertilizers than from manure on cabbage.

TABLE 20.—Comparison of Highest Yielding Chemical Treatment With 20 Tons of Manure Per Acre

Average annual increase over unfertilized checks in pounds per acre, last 4 years, 1923-1926

	Chemical treatment		Manure Plot 5	Difference in favor of manure
	Plot	Increase		
Cucumbers	8	4923	7958	3035
Sweet corn	14	1487	1917	430
Tomatoes	6	3190	3552	362
Cabbage	8	5927	4157	—1770

Aside from the results with cabbage, there is a larger difference in favor of manure during the last four years than during the first eight. As far as cucumbers and sweet corn are concerned, it is probable that part of the difference in favor of manure is due to the larger amounts of nitrogen supplied by the manure than by the chemicals. Residual effects from continuous manuring would be expected to accentuate these differences due to nitrogen as the experiment progressed.

In view of the indication that the conspicuous difference on cucumbers could be reduced by larger amounts of nitrogen in a chemical fertilizer, together with the fact that the difference in favor of manure on tomatoes is less than 4 percent of the yield, the results, as a whole, of the first 12 years of the experiment are encouraging to the truck grower who is forced by the shortage of manure to rely upon chemical fertilizers and cover crops for the maintenance of fertility.

INCREASE IN INCOME FROM FERTILIZERS

The increase in income as used here is not actual profit in the customary sense of the word, but denotes the increase in returns from the fertilized plots over the returns from the unfertilized plots, with no deduction for any increased costs except that of the fertilizer. The calculations are based on actual prices received for the produce when sold thru the Marietta Truck Growers' Association. These returns are summarized in Tables 21 and 22 primarily to demonstrate that returns from the use of chemical fertilizers are in most instances much greater than the cost of the fertilizer. This fact has not been emphasized in the preceding pages, partly because prices of produce vary from season to season, consequently predictions of increase in income are more uncertain than predictions of increase in yield. But as the grower is primarily interested in financial returns, the accompanying summary tables are presented by way of conclusion. The gratifying returns from the three leading crops of the district, cabbage, tomatoes, and cucumbers, as shown in these tables need but little discussion.

A critical comparison of the costs of fertilizers and the increased income from them as shown in these tables illustrates three of the economic principles that complicate the fertility problem. First, the profit from fertilization depends to a large degree upon the per-acre value of the crop. With cabbage,

TABLE 21.—Average Annual Increase in Income Due to Fertilizers

Selected plots from series A, 4-year average, 1923-1926, dollars per acre

	Plot number and annual treatment per acre						
	11	15	9	6	8	3	2
	Super-phos. 800 lb.	Nitrate of soda*	Nitrate of soda 320 lb. super-phos. 800 lb.	Nitrate of soda 320 lb. superphos. 800 lb. potash 100 lb.	Nitrate of soda 480 lb. superphos. 1200 lb. potash 150 lb.	Manure 16 T.	Manure 16 T. superphos. 800 lb.
	$8.00	*	$17.60	$20.60	$30.90	$60.00	$68.00
Cabbage	29.00	75.59	163.33	175.43	212.47	55.77	72.23
Tomatoes	26.20	18.77	83.20	86.20	78.80	73.90	66.10
Cucumbers	2.50	16.50	100.90	110.37	91.80	132.17	145.03
Sweet corn	—10.13	12.73	—3.50	—2.97	—25.90	—31.77	—42.73

*On tomatoes and sweet corn, 320 pounds, $9.60; on cabbage and cucumbers, 480 pounds, $14.40.

cucumbers, and tomatoes, which showed large gross values per acre, any fertilizer that materially increases the yield produced returns far above the cost of the fertilizer. With sweet corn, which has a relatively low value per acre at Marietta, many of the increases in yield did not cover the cost of the fertilizer.

TABLE 22.—Average Annual Increase in Income Due to Fertilizers

Selected plots from series B, 12-year averages, 1915-1926, dollars per acre

	Plot number and annual treatment per acre							
	33	36	34	31	24	25	28	26
	Lime 1 T.	Superphos. 400 lb. lime 1 T.	Nitrate of soda 160 lb. superphos. 400 lb. lime 1 T.	Nitrate of soda 160 lb. superphos. 400 lb. potash 50 lb. lime 1 T.	Manure 16 T.	Manure 16 T. lime 1 T.	Manure 16 T. superphos. 400 lb. lime 1 T.	Manure 16 T. nitrate of soda 160 lb. superphos. 400 lb. lime 1 T.
	$5.00	$9.00	$13.80	$15.30	$60.00	$65.00	$69.00	$73.80
Cabbage	78.18	94.95	203.79	229.86	197.36	232.29	218.92	300.86
Tomatoes	4.40	38.47	88.65	73.57	136.65	133.52	146.15	143.85
Cucumbers	1.36	2.17	38.89	91.96	154.80	182.23	165.86	243.07
Sweet corn	8.41	—5.84	10.53	10.41	—9.17	—7.50	—7.77	—16.81

Second, the largest returns per dollar invested in fertilizer were from the initial applications of the limiting elements. For example, lime alone on cabbage (Plot 33) showed an increased income of $78.18 at a cost of $5.00 per acre, a return of $15.63 for each dollar invested. Similarly, altho less conspicuously, nitrate of soda and superphosphate (Plot 9) gave an average return of $100 on cucumbers and $83 on tomatoes at a cost of $17.60, which is $5.68 and $4.73, respectively, for each dollar invested. Some of the larger treatments have given larger increases in income per acre, and are therefore recommended, but none have given as large returns per dollar as the initial application of essential chemicals.

Third, increasing the amount of fertilizer usually increases the income until a point is reached where the diminishing returns fail to cover the additional cost. With tomatoes, for example, the largest application of chemicals in series A (Plot 8) appears to be beyond the profitable limit of the fertilizer combination used here. With cabbage there is no indication that this limit was reached. At the other extreme, with sweet corn, only the nitrogenous fertilizers were profitable.

Altho these returns are based on local and fluctuating conditions they well illustrate the necessity of considering, in any economical fertilizer program, not only the crop's requirements but also the cost of the fertilizer and the probable value of the crop.

TABLE 23.—Cabbage, Series A

Average annual yield, increase due to treatment, gross receipts, and profit due to treatment, on a per acre basis

Plot	Annual treatment, pounds per acre	Yield	Increase over checks	Gross receipts	Cost of treatment	Profit
		Lb.	Lb.	Dol.	Dol.	Dol.
	First 8 years, 1915–1922					
1	None	15,905	.....	389.68	.....	.....
2	Manure 16 tons, superphosphate 400	20,907	4,896	534.38	64.00	78.44
3	Manure 16 tons	20,005	3,886	521.51	60.00	67.32
4	None	16,225	.....	396.45	.....	.....
5	Manure 16 tons	19,400	3,275	496.71	60.00	42.58
6	Nitrate soda 320, superphosphate 800, muriate potash 100	20,900	4,875	581.11	20.60	168.70
7	None	15,925	.....	389.49	.....	.....
8	Nitrate soda 160, superphosphate 400, muriate potash 50	19,225	3,471	510.05	10.30	112.71
9	Nitrate soda 160, superphosphate 400	19,077	3,496	501.52	8.80	108.12
10	None	15,410	.....	382.15	.....	.....
11	Superphosphate 400	16,960	1,728	416.13	4.00	40.66
12	Nitrate soda 80, sulfate ammonia 65	16,465	1,412	411.61	4.35	46.46
13	None	14,875	.....	350.12	.....	.....
14	Nitrate soda 160, in two applications	16,120	1,640	392.81	4.80	45.13
15	Nitrate soda 160, in one application	16,070	1,985	391.63	4.80	51.18
16	None	13,690	.....	328.41	.....	.....
	Last 4 years, 1923–1926					
1	None	18,330	.....	396.20	.....	.....
2	Manure 16 tons, superphosphate 800	22,860	3,967	549.80	68.00	72.23
3	Manure 16 tons	22,870	3,413	538.70	60.00	55.77
4	None	20,020	.....	436.30	.....	.....
5	Manure 20 tons	24,420	4,157	558.30	75.00	43.57
6	Nitrate soda 320, superphosphate 800, muriate potash 100	25,440	4,933	639.20	20.60	175.43
7	None	20,750	.....	446.60	.....	.....
8	Nitrate soda 480, superphosphate 1200, muriate potash 150	26,320	5,927	689.50	30.90	212.47
9	Nitrate soda 320, superphosphate 800	24,040	4,003	626.60	17.60	163.33
10	None	19,680	.....	445.20	.....	.....
11	Superphosphate 800	20,240	943	456.70	8.00	29.00
12	Sulfate ammonia 390	20,570	1,657	446.00	11.70	40.10
13	None	18,530	.....	368.70	.....	.....
14	Nitrate soda 480, in two applications	23,730	3,613	495.10	14.40	111.85
15	Nitrate soda 480, in one application	20,300	1,517	459.00	14.40	75.59
16	None	18,910	.....	369.16	.....	.....

TABLE 24.—Cabbage, Series B

Average annual yield, increase due to treatment, gross receipts, and profit due to treatment, on a per acre basis

Averages for the first 8 years, 1915-1922; the last 4 years, 1923-1926; and the entire 12 years, 1915-1926

Plot	Annual treatment, pounds per acre	Annual yield			Increase over checks			Gross receipts			Cost of treat-ment	In-crease in income 12-yr. av.
		First 8 yrs.	Last 4 yrs.	12 yrs.	First 8 yrs.	Last 4 yrs.	12 yrs.	First 8 yrs.	Last 4 yrs.	12 yrs.		
		Lb.	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Dol.*	*Dol.*	*Dol.*	*Dol.*	*Dol.*
21	Manure 8 tons, nit. soda 320, superphos. 800, mur, potash 100, lime 1 ton.	*	22,790	....	....	8,980	....	....	520.90	....	55.60	....
22	None........	14,055	13,810	13,973	....	....	....	285.26	266.90	279.14	....	....
23	Manure 16 tons, nit. soda 160, superphosphate 400, mur. potash 50........	23,887	27,770	25,181	9,686	13,728	11,033	601.14	639.70	613.99	70.30	254.92
24	Manure 16 tons........	21,645	25,610	22,967	7,444	12,235	9,041	530.15	583.40	547.90	60.00	197.36
25	Manure 16 tons, limestone 1 ton........	22,325	27,760	24,137	8,124	13,252	9,833	568.70	631.40	589.60	65.00	232.29
26	Manure 16 tons, nitrate soda 160, superphosphate 400, limestone 1 ton...	24,930	31,770	27,210	10,729	17,029	12,829	631.47	743.30	668.75	73.80	300.86
27	Manure 16 tons........	21,125	27,390	23,213	6,924	12,416	8,755	508 51	587.50	534.84	60.00	178.99
28	Manure 16 tons, superphosphate 400, limestone 1 ton........	22,755	28,100	24,537	8,554	12,893	10,000	569.87	616.90	585.55	69.00	218.92
29	None........	14,347	15,440	14,711	....	....	....	308.82	304.10	307.25	....	....
30	Nitrate soda 160, superphosphate 400, muriate potash 50........	19,335	21,860	20,177	5,233	7,007	5,824	449.19	523.90	474.09	10.30	170.26
31	Limestone 1 ton, nit. soda 160, superphosphate 400, mur. potash 50........	20,660	24,050	21,790	6,803	9,783	7,796	500.54	573.90	524.99	15.30	229.86
32	None........	13,612	13,680	13,635	....	....	....	257.53	283.30	266.12	....	....
33	Limestone 1 ton........	15,990	17,240	16,407	2,733	3,630	3,032	345.77	348.30	346.61	5.00	78.18
34	Limestone 1 ton, nitrate soda 160, superphosphate 400........	19,960	23,180	21,033	7,060	9,640	7,920	466.40	502.20	478.33	13.80	203.79
35	None........	12,545	13,470	12,853	....	....	....	251.22	271.70	258.05	....	....
36	Limestone 1 ton, superphosphate 400........	16,220	18,280	16,907	3,675	4,810	4,053	348.44	389.10	361.97	9.00	94.95

*A straw mulch applied to plot 21 during the first 8 years depressed the yield and was replaced by the treatment given above.

TABLE 25.—Tomatoes, Series A

Average annual yield, increase due to treatment, gross receipts, and profit due to treatment, on a per acre basis

Plot	Annual treatment, pounds per acre	Yield Lb.	Increase over checks Lb.	Gross receipts Dol.	Cost of treatment Dol.	Profit Dol.
	First 8 years, 1915–1922					
1	None	10,188	....	377.66	....	....
2	Manure 16 tons, superphosphate 400	14,485	4,245	530.71	64.00	90.41
3	Manure 16 tons	13,803	3,512	512.32	60.00	77.38
4	None	10,343	....	373.58	....	....
5	Manure 16 tons	13,255	2,881	464.57	60.00	35.55
6	Nitrate soda 320, superphosphate 800, muriate potash 100	13,138	2,733	469.05	20.60	84.00
7	None	10,436	....	359.89	....	....
8	Nitrate soda 160, superphosphate 400, muriate potash 50	11,913	1,563	427.86	10.30	56.74
9	Nitrate soda 160, superphosphate 400	11,480	1,217	406.84	8.80	36.28
10	None	10,177	....	362.69	....	....
11	Superphosphate 400	11,345	1,590	393.65	4.00	42.61
12	Nitrate soda 80, sulfate ammonia 65	9,778	445	334.63	4.35	—1.11
13	None	8,911	....	315.74	....	....
14	Nitrate soda 160, in two applications	9,182	384	334.77	4.80	20.06
15	Nitrate soda 160, in one application	9,128	444	329.53	4.80	20.65
16	None	8,571	....	298.25	....	....
	Last 4 years, 1923–1926					
1	None	9,355	....	382.20	....	....
2	Manure 16 tons, superphosphate 800	13,015	3,912	503.50	68.00	66.10
3	Manure 16 tons	12,507	3,655	490.50	60.00	73.90
4	None	8,600	....	343.80	....	....
5	Manure 20 tons	11,912	3,552	450.90	75.00	45.80
6	Nitrate soda 320, superphosphate 800, muriate potash 100	11,310	3,190	423.20	20.60	86.20
7	None	7,880	....	302.70	....	....
8	Nitrate soda 480, superphosphate 1200, muriate potash 150	10,945	2,873	419.30	30.90	78.80
9	Nitrate soda 320, superphosphate 800	9,690	1,425	417.30	17.60	83.20
10	None	8,451	....	323.40	....	....
11	Superphosphate 800	9,035	1,065	342.80	8.00	26.20
12	Sulfate ammonia 260	7,560	78	304.30	7.80	2.70
13	None	6,995	....	279.00	....	....
14	Nitrate soda 320, in two applications	8,035	992	317.30	9.60	30.43
15	Nitrate soda 320, in one application	7,760	668	303.90	9.60	18.77
16	None	7,140	....	273.80	....	....

TABLE 26.—Tomatoes, Series B

Average annual yield, increase due to treatment, gross receipts, and profit due to treatment, on a per acre basis

Averages for the first 8 years, 1915-1922; the last 4 years, 1923-1926; and the entire 12 years, 1915-1926

Plot	Annual treatment, pounds per acre	Annual yield			Increase over checks			Gross receipts			Cost of treatment	Increase in income 12-yr. av.
		First 8 yrs.	Last 4 yrs.	12 yrs.	First 8 yrs.	Last 4 yrs.	12 yrs.	First 8 yrs.	Last 4 yrs.	12 yrs.		
		Lb.	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Dol.*	*Dol.*	*Dol.*	*Dol.*	*Dol.*
21	Manure 8 tons, nit. soda 320, superphos. 800, mur. pot. 100, limestone 1 T.	*	11,485	....	....	4020	....	....	497.00	....	55.60	....
22	None	7,687	7,465	7,613	....	....	....	287.28	355.00	309.85	....	....
23	Manure 16 tons, nit. soda 160, superphos. 400, mur. potash 50	13,412	13,775	13,533	5620	6371	5870	485.62	606.30	525.85	70.30	146.34
24	Manure 16 tons	12,673	13,305	12,883	4881	5962	5241	468.52	570.40	502.48	60.00	136.65
25	Manure 16 tons, limestone 1 ton	13,663	12,685	13,137	5571	5403	5515	487.11	528.70	500.97	65.00	133.52
26	Manure 16 tons, nitrate soda 160, superphosphate 400, limestone 1 ton	13,377	14,460	14,471	5585	7239	6136	490.84	568.50	516.73	73.80	143.85
27	Manure 16 tons	12,703	14,015	13,140	4911	6855	5559	462.22	561.00	495.15	60.00	139.44
28	Manure 16 tons, superphosphate 400, limestone 1 ton	13,743	13,287	13,591	5951	6188	6030	503.01	516.40	507.47	69.00	146.15
29	None	7,897	7,040	7,611	....	....	....	295.48	284.10	291.69	....	....
30	Nitrate soda 160, superphosphate 400, muriate potash 50	9,673	8,705	9,350	2384	2067	2278	364.71	407.40	378.94	10.30	92.55
31	Nitrate soda 160, superphosphate 400, mur. potash 50, limestone 1 ton	9,128	9,192	9,149	2448	2958	2618	336.52	375.10	349.46	15.30	73.57
32	None	6,072	5,832	5,922	....	....	....	225.41	283.90	244.90	....	....
33	Limestone 1 ton	6,715	6,195	6,542	622	134	459	251.98	251.90	251.95	5.00	4.40
34	Limestone 1 ton, nitrate soda 160, superphosphate 400	9,153	8,335	8,880	3037	2044	2706	341.67	344.60	342.65	13.80	88.65
35	None	6,137	6,520	6,265	....	....	....	224.41	264.70	237.84	....	....
36	Limestone 1 ton, superphosphate 400	7,771	6,600	7,381	1634	80	1116	290.93	274.10	285.32	9.00	38.47

*A straw mulch applied to Plot 21 during the first 8 years depressed the yield and was replaced by the treatment given above.

TABLE 27.—Cucumbers, Series A

Average annual yield, increase due to treatment, gross receipts, and profit due to treatment, on a per acre basis

Plot	Annual treatment, pounds per acre	Yield	Increase over checks	Gross receipts	Cost of treatment	Profit
		Lb.	Lb.	Dol.	Dol.	Dol.
	First 8 years, 1915–1922					
1	None	15,346	....	235.80	....	....
2	Manure 16 tons, superphosphate 400	19,340	4,034	331.06	64.00	28.76
3	Manure 16 tons	18,567	3,302	309.22	60.00	8.41
4	None	15,225	....	243.31	....	....
5	Manure 16 tons	19,549	4,260	336.56	60.00	32.54
6	Nitrate soda 320, superphosphate 800, muriate potash 100	19,619	4,265	338.39	20.60	73.07
7	None	15,418	....	245.43	....	....
8	Nitrate soda 160, superphosphate 400, muriate potash 100	19,236	3,654	312.48	10.30	57.80
9	Nitrate soda 160, superphosphate 400	19,450	3,703	319.44	8.80	67.32
10	None	15,911	....	242.27	....	....
11	Superphosphate 400	17,498	1,656	262.75	4.00	18.71
12	Nitrate soda 80, sulfate ammonia 65	17,547	1,776	260.06	4.35	17.89
13	None	15,702	....	235.59	....	....
14	Nitrate soda 160, in two applications	16,004	1,009	238.98	4.80	8.27
15	Nitrate soda 160, in one application	16,295	2,009	243.32	4.80	22.28
16	None	13,579	....	206.56	....	....
	Last 4 years, 1923–1926					
1	None	14,095	....	258.90	....	....
2	Manure 16 tons, superphosphate 800	23,160	8,157	485.20	68.00	145.03
3	Manure 16 tons	23,060	7,148	477.60	60.00	132.17
4	None	16,820	....	298.70	....	....
5	Manure 20 tons	24,370	7,958	498.60	75.00	130.33
6	Nitrate soda 320, superphosphate 800, muriate potash 100	20,170	4,167	418.80	20.60	110.37
7	None	15,595	....	282.40	....	....
8	Nitrate soda 480, superphosphate 1200, muriate potash 150	19,805	4,923	391.40	30.90	91.80
9	Nitrate soda 320, superphosphate 800	18,050	3,882	373.50	17.60	100.90
10	None	13,455	....	241.30	....	....
11	Superphosphate 800	13,280	—23	248.80	8.00	2.50
12	Sulfate ammonia 390	11,700	—1,452	203.50	11.70	—43.50
13	None	13,000	....	232.30	....	....
14	Nitrate soda 480, in two applications	13,075	775	253.00	14.40	15.60
15	Nitrate soda 480, in one application	12,400	800	244.60	14.40	16.50
16	None	10,900	....	204.40	....	....

TABLE 28.—Cucumbers, Series B

Average annual yield, increase due to treatment, gross receipts, and profit due to treatment, on a per acre basis

Averages for the first 8 years, 1915-1922; the last 4 years, 1923-1926; and the entire 12 years, 1915-1926

Plot	Annual treatment, pounds per acre	Annual yield			Increase over checks			Gross receipts			Cost of treatment	Increase in income 12-yr. av.
		First 8 yrs.	Last 4 yrs.	12 yrs.	First 8 yrs.	Last 4 yrs.	12 yrs.	First 8 yrs.	Last 4 yrs.	12 yrs.		
		Lb.	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Dol.*	*Dol.*	*Dol.*	*Dol.*	*Dol.*
21	Manure 8 tons, nit. soda 320, superphos. 800, mur. potoash 100, lime 1 ton	*	21,940	....	....	11,500	....	....	432.90	....	55.60	....
22	None	11,076	10,440	10,864	....	....	....	161.64	153.90	159.06	....	....
23	Manure 16 tons, nit. soda 160, superphos. 400, mur. potash 50	19,825	23,615	21,088	6,900	12,839	8,879	338.70	488.90	388.77	70.30	131.13
24	Manure 16 tons	19,832	26,610	22,158	6,907	15,500	9,771	326.13	564.40	405.55	60.00	154.80
25	Manure 16 tons, limestone 1 ton	22,061	28,000	24,041	9,136	16,556	11,609	373.90	576.40	441.40	65.00	182.23
26	Manure 16 tons, nit. soda 160, superphos. 400, limestone 1 ton	25,978	31,740	27,899	13,053	19,962	15,356	435.87	671.60	514.45	73.80	243.07
27	Manure 16 tons	21,640	27,020	23,433	8,715	14,908	10,779	345.73	539.50	410.32	60.00	149.33
28	Manure 16 tons, superphosphate 400, limestone 1 ton	23,528	26,340	24,465	10,603	13,894	11,700	391.45	534.90	439.27	69.00	165.86
29	None	14,775	12,780	14,110	....	....	....	236.22	225.60	232.68	....	....
30	Nitrate soda 160, superphosphate 400 muriate potash 50	20,610	16,820	19,347	6,099	5,187	5,795	344.53	336.60	341.89	10.30	106.91
31	Limestone 1 ton, nit. soda 160, superphos. 400, mur. potash 50	20,086	15,555	18,576	5,841	5,068	5,583	333.70	304.40	323.93	15.30	91.96
32	None	13,981	9,340	12,434	....	....	....	229.85	166.30	208.67	....	....
33	Limestone 1 ton	13,452	7,430	11,445	588	—1,207	—10	227.68	131.60	195.65	5.00	1.36
34	Limestone 1 ton, nitrate soda 160, superphosphate 400	15,356	8,620	13,111	3,609	687	2,635	253.73	160.40	222.62	13.80	38.89
35	None	10,630	7,230	9,497	....	....	....	168.38	114.90	150 55	....	....
36	Limestone 1 ton, superphosphate 400	11,111	7,110	9,777	481	—120	281	181.59	122.00	161.73	9.00	2.17

*A straw mulch applied to Plot 21 during the first 8 years depressed the yield and was replaced by the treatment given above.

TABLE 29.—Sweet Corn, Series A

Average annual yield, increase due to treatment, gross receipts, and profit due to treatment, on a per acre basis

Plot	Annual treatment, pounds per acre	Yield Lb.	Increase over checks Lb.	Gross receipts Dol.	Cost of treatment Dol.	Profit Dol.
	First 8 years, 1915-1922					
1	None	7,520		147.57		
2	Manure 16 tons, superphosphate 400	7,960	471	161.94	64.00	—48.28
3	Manure 16 tons	7,960	503	158.55	60.00	—46.32
4	None	7,425		143.52		
5	Manure 16 tons	8,290	955	162.28	60.00	—38.86
6	Nitrate soda 320, superphosphate 800, muriate potash 100	8,115	870	160.08	20.60	.72
7	None	7,155		136.38		
8	Nitrate soda 160, superphosphate 400, muriate potash 50	7,840	635	153.27	10.30	4.83
9	Nitrate soda 160, superphosphate 400	8,055	800	157.31	8.80	8.61
10	None	7,305		141.66		
11	Superphosphate 400	7,775	464	149.70	4.00	5.76
12	Nitrate soda 80, sulfate ammonia 65	7,525	206	143.13	4.35	.56
13	None	7,325		136.50		
14	Nitrate soda 160, in two applications	7,515	216	143.98	4.80	2.59
15	Nitrate soda 160, in one application	7,580	309	140.97	4.80	—.52
16	None	7,245		136.78		
	Last 4 years, 1923-1926					
1	None	7,490		159.10		
2	Manure 16 tons, superphosphate 800	9,040	1,317	185.60	68.00	—42.73
3	Manure 16 tons	9,430	1,473	189.80	60.00	—31.77
4	None	8,190		162.80		
5	Manure 20 tons	9,770	1,917	195.90	75.00	—33.23
6	Nitrate soda 320, superphosphate 800, muriate potash 100	8,230	713	163.10	20.60	— 2.97
7	None	7,180		136.80		
8	Nitrate soda 480, superphosphate 1,200, muriate potash 150	7,610	393	140.80	30.90	—25.90
9	Nitrate soda 320, superphosphate 800	7,640	387	148.90	17.60	— 3.50
10	None	7,290		133.80		
11	Superphosphate 800	7,040	—167	131.10	8.00	—10.13
12	Sulfate ammonia 260	8,510	1,387	162.90	7.80	22.43
13	None	7,040		132.10		
14	Nitrate soda 320, in two applications	8,590	1,487	159.50	9.60	18.37
15	Nitrate soda 320, in one application	8,250	1,083	153.30	9.60	12.73
16	None	7,230		130.40		

TABLE 30.—Sweet Corn, Series B

Average annual yield, increase due to treatment, gross receipts, and profit due to treatment, on a per acre basis

Averages for the first 8 years, 1915-1922; the last 4 years, 1923-1926; and the entire 12 years, 1915-1926

Plot	Annual treatment, pounds per acre	Annual yield			Increase over check			Gross receipt			Cost of treatment	Increase in income 12-yr. av.
		First 8 yrs.	Last 4 yrs.	12 yrs.	First 8 yrs.	Last 4 yrs.	12 yrs.	First 8 yrs.	Last 4 yrs.	12 yrs.		
		Lb.	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Dol.*	*Dol.*	*Dol.*	*Dol.*	*Dol.*
21	Manure 8 tons, nit. soda 320, superphos. 800, mur. potash 100 ,lime 1 ton	*	8,940	....	....	2080	....	....	166.60	....	55.60	....
22	None	6010	6,860	6293	....	....	....	111.07	123.90	115.35	....	....
23	Manure 16 tons, nit. soda 160, superphos. 400, mur. potash 50	8395	9,430	8740	1883	2597	2121	163.72	175.00	167.48	70.30	—24.41
24	Manure 16 tons	8520	9,940	8993	2008	3134	2383	166.58	184.30	172.49	60.00	—9.17
25	Manure 16 ton, limestone 1 ton	8765	10,610	9380	2253	3831	2779	169.89	197.90	179.23	65.00	—7.50
26	Manure 16 tons, nitrate soda 160, superphosphate 400, limestone 1 ton	8870	10,200	9313	2358	3448	2721	172.87	190.60	178.78	73.80	—16.81
27	Manure 16 tons	8685	10,980	9450	2173	4255	2867	169.79	200.50	180.03	60.00	—1.83
28	Manure 16 tons, superphosphate 400, limestone 1 ton	9135	10,200	9490	2623	3502	2916	180.18	189.10	183.15	69.00	—7.77
29	None	7015	6,670	6900	....	....	....	129.61	125.30	128.17	....	....
30	Nitrate soda 160, superphosphate 400, muriate potash 50	7965	8,190	8040	1055	1680	1263	151.29	154.50	152.36	10.30	15.79
31	Limestone 1 ton, nit. soda 160, superphos. 400, mur. potash 50	8075	7,620	7923	1270	1270	1270	153.39	143.40	150.06	15.30	10.41
32	None	6700	6,190	6530	....	....	....	124.02	119.30	122.45	....	....
33	Limestone 1 ton	7415	6,500	7110	910	273	698	136.98	124.40	132.79	5.00	8.41
34	Limestone 1 ton, nitrate soda 160, superphosphate 400	7560	7,370	7497	1250	1107	1202	140.54	140.80	140.63	13.80	10.53
35	None	6115	6,300	6177	....	....	....	110.24	119.20	113.23	....	....
36	Limestone 1 ton, superphosphate 400	6360	6,570	6430	245	270	253	114.73	119.70	116.39	9.00	—5.84

*A straw mulch applied to Plot 21 during the first 8 years depressed the yield, and was replaced by the treatment given above.